MAUI [HAWAII]

AMOS

spring 2005

Air Force Research Laboratory DETACHMENT 15

AIR FORCE MAUI OPTICAL & SUPERCOMPUTING SITE

LOST IN SPACE, AN AMOS INITIATIVE FOR FINDING OBJECTS IN SPACE

LOST AND FOUND: FOR THOSE OF US WHO ARE EASILY DISTRACTED BY THE HECTIC ACTIVITIES OF OUR DAILY LIVES, WE ARE OCCASIONALLY PRONE TO MISPLACE THINGS: A PAIR OF READING GLASSES, THE CAR KEYS, THE KIDS. ROCKET SCIENTISTS ARE NO EXCEPTION WHEN IT COMES TO LOSING TRACK OF THEIR PERSONAL BELONGINGS, ONLY IT CAN BE A BIT EMBARRASSING TO ADMIT IT WHEN THE OBJECT YOU MISPLACED HAPPENS TO BE, SAY, A SEVERAL TON EXPENDED ROCKET BOOSTER ORBITING THE EARTH.

But when you consider that there are over 12,000 known human-made objects orbiting our planet (see Figure 1), and many more that we don't know about, an occasional lapse in the accounting department is understandable. These misplaced objects can include miscellaneous space junk, old rocket bodies, and dead payloads. Maybe your car keys are up there?

We typically keep track of objects orbiting the Earth by observing them with radar and/or optical tracking systems geographically distributed around the globe. But there is a lot to keep track of up there, so sometimes an adverse combination of viewing geometry from the tracking sites, object size, distance, the lighting conditions, accuracy of the tracking metrics, and the laws of physics (not to mention the ever present laws of Murphy) conspire to prevent the tracking quality necessary to maintain adequate knowledge of every object's location. Adequate knowledge of where it is "now" is necessary in order to accurately predict where it will be at a future time. Knowing the location of objects orbiting the Earth is extremely important to ensuring the safety, health, and welfare of active commercial, scientific, and military space assets. It wouldn't take a very large projectile hurtling through orbit at several thousand meters per second to cause severe damage to a billion dollar satellite. "Danger! Danger Will Robinson!"

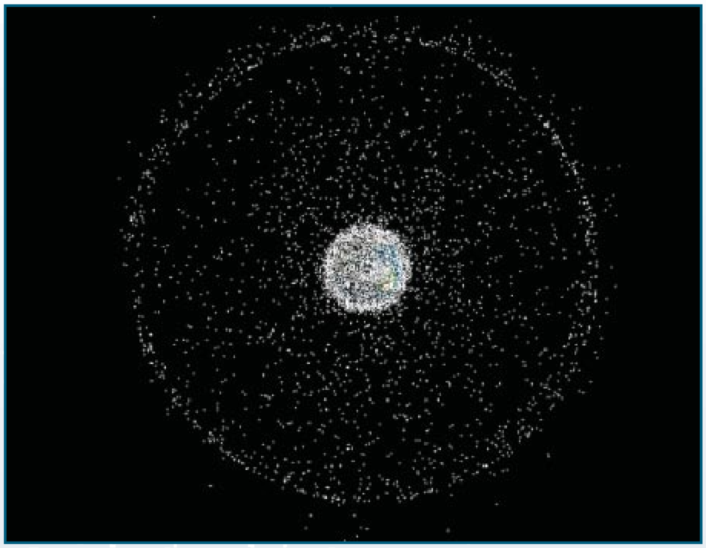


FIGURE 1: Debris Cloud of more than 12,000 Objects Orbiting Earth

ALL IS NOT LOST:

Through a collaborative effort, the Air Force Research Laboratory (AFRL) Det 15, Boeing LTS Maui, NASA, and Oceanit, Inc. are teaming up for an initiative that will utilize AMOS resources to develop technologies and processes to assist in finding lost objects and, of equal importance, keeping them found. Optical tracking systems under development and in use at AMOS, such as the Phoenix and High Accuracy Network Determination System (HANDS)/Raven systems, combine with the unique geographical location of Maui to provide the ideal test-bed for development of systems and processes to help us keep track of the growing number of space objects.

One of the chief advantages of optical systems is that, by design, they can survey well-defined areas of the sky. For example, the Phoenix sensor system (see Spring 2004 AMOS Newsletter), developed and integrated at the AMOS Remote Maui Experimental (RME) site in Kihei, has optics that allow us to see a relatively large piece of the sky compared to the field-of-view (FOV) currently provided by most optical sensors. Searches for lost objects using Phoenix will take much less time compared to the more typical sensor FOV of a few square degrees. Newer systems under

(continued inside)

Lost in Space (cont.)

development at AMOS, such as HANDS/Raven, provide the higher accuracy metrics – the instantaneous object location in the sky – that allow accurate orbit determination to be done, giving us the high accuracy predictions which allow us to find objects the next time around in their orbit cycle. A Meter Class Acquisition Telescope (MCAT) having 1-meter 2.5° diagonal FOV is under development at Oceanit (see Figure 2). This system will combine the advantages of the Phoenix wide FOV (WFOV) and HANDS/Raven high accuracy metrics; the ideal tool for finding lost objects and keeping them found.

Look What the MCAT Dragged In:

An example of lost objects that the Air Force is interested in finding are the Initial Defense Communications Satellite Program (IDCSP) objects, a constellation of 34 prototype communications satellites launched into sub-geosynchronous orbit between 1966 and 1968 (see Figure 3). Though no longer in service, their proximity to geosynchronous orbit makes them a potential hazard for satellites wanting to get to the hottest property in space for telecommunications satellites. The small size and surface makeup of the IDCSPs, combined with their high orbital altitudes, make them extremely challenging to passively track, and hence over the course of time they have become lost. Their orbit characteristics indicate that they should drift into view for a period of around 3-4 days, and then disappear again for 7-10 days. An added challenge to finding the objects is that they periodically go into eclipse, that is, their position in orbit is shaded from the Sun by the Earth. Without direct sunlight they do not reflect, so are not visible to optical tracking systems.

We do have some historical knowledge of where lost objects used to be before they became lost. Thanks to Sir Isaac Newton and others, having knowledge of an object's position and velocity at a given time, we can describe the orbital motion analytically using equations and computers to predict where it will be at a future time. However, like the weather, there are just too many variables in the real world to allow us to perfectly model orbital motion using equations and computers, and our predicted location grows more uncertain with time. We do know that the orbit plane of an object orbiting the Earth is relatively stable and predictable over long periods of time. It's our knowledge of exactly where the object is in its orbit that degrades rather quickly as we get further away in time from its last known position.

But all is not lost! If you think of the orbital paths as "highways" (see Figure 4), even without any knowledge of where the satellites are located in their orbits, one can establish a strategy that searches along an orbit track – the orbit dimension that has the most uncertainty associated with it. Or, as in the case of the IDCSP constellation where we have multiple orbit planes, we might stake out a node where the planes intersect to increase the likelihood of seeing one of the objects at a given time. Objects must eventually pass any given point in its orbit plane, so it's just a matter of time, and maybe a little patience before it passes through the field-of-view of the telescope. Okay, so maybe a little luck wouldn't hurt either (but you didn't hear a rocket scientist say that).

Finders Keepers:

This "lost object" initiative falls under the auspices of Space Situational Awareness. Once we've found a lost object, to keep it found, we must be able to find it again at any point in the future. Studies conducted at AMOS indicate that the metric measurements provided by Phoenix collected during the 3-4 nights when the IDCSP objects are visible should result in orbit determination accuracies more than good enough to allow us to predict their location 7-10 days in the future. Tracking and analysis experiments are currently being conducted at AMOS to validate the system and processes just described. So stay tuned for future episodes of the AMOS newsletter for results.

Figure 2: K-Star Development – A Prototype to the WFOV MCAT

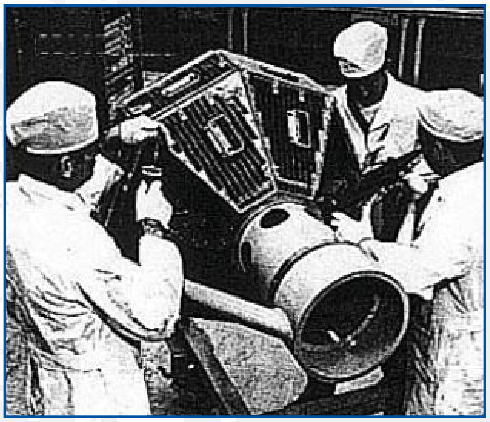


Figure 3: "Doctor Rocket" and His Assistants Operate on an IDCSP Satellite

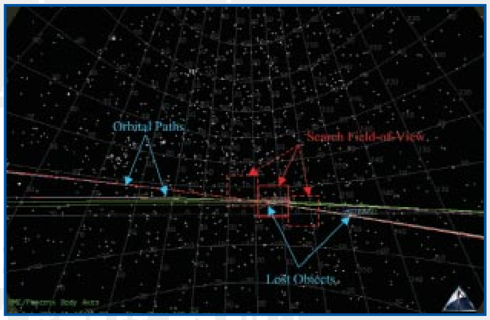


Figure 4: Lost Object Search Strategy for Finding IDCSP

Photometry Lab at the Remote Maui Experiment (RME) Site

Air Force Maui Optical and Supercomputing (AMOS) personnel have been addressing the problem of determining physical, material, and orbital characteristics of orbital objects ranging from those in near-earth orbit (NEO) to those in solar orbit, but whose orbits bring them within observational range of Earth observatories. Many of these observable objects are non-resolvable from ground-based telescopes, with photometric intensities being virtually the only available optical data. AMOS researchers have developed theoretical light curves for simple to complex geometries, and applied these geometries to simple and increasingly complex orbits and object orientations. AMOS personnel have matched the theoretical curves with some simple light curves obtained from simple orbital objects. However, a fully realistic computer model simulating the optical characteristics of a satellite is difficult for two main reasons: factors such as shadowing and complex surface shapes are difficult to simulate, and require an extraordinary amount of computing time to obtain results, and few real surfaces act only as simple specular or diffuse reflectors.

The AMOS Photometry Laboratory Robot Arm.

The AMOS Photometry Lab, located at the Remote Maui Experiment (RME) site, is being created in order to address the photometry problem in a unique manner. The lab consists of a standard CCD camera, light source, and a robotic arm capable of 5 degrees of freedom. The robotic arm can be programmed to reproduce the relative orientation between the test satellite and the Earth (camera). Satellite models (up to a maximum weight of 4 kg) will be constructed and placed at the end of the robot arm, and then manipulated in such a manner as to simulate the orbital attitudes and satellite motion (rotation, etc.) The resulting photometric data will be handled as if it were non-resolvable (e.g., only total pixel counts will be utilized) and photometric curves will be obtained.

The first test of the photometry of a velocity-oriented, Earth-facing object produced photometric curves virtually identical to those produced by the simulations.

Future plans include the incorporation of computer control of the robot motion, allowing direct production of satellite orientations from orbital and satellite orientation data, and construction of realistic satellite models. Validation will be accomplished by comparing lab results with actual data from AMOS observatory files.

Department of Defense Awards HPC Upgrade to Maui High Performance Computing Center

The Department of Defense (DoD) High Performance Computing Modernization Program (HPCMP) provides supercomputing and related services, high-speed network communications, and computational science expertise enabling research to solve the most challenging problems facing the research, development, and test communities. This enabling technology places advanced systems and capabilities into the hands of U.S. Forces more quickly, less expensively, and with greater certainty of success.

Annually, the DoD HPCMP makes selected acquisitions of High Performance Computing (HPC) systems for its program. This collective award and acquisition process is known as the Technology Insertion process. On 27 August 2004, the Maui High Performance Computing Center was named as a recipient of a Fiscal Year 2005 HPC award. The system proposed supports an Advanced Image Reconstruction project under the Maui Space Surveillance System.

In the spring of 2005, MHPCC will add a Cray XD1 System to its computational inventory. The System consists of 288, 2.6 GHz Opteron processors capable of delivering a peak throughput of 1.5 TeraFLOPS with 4 GB of memory per processor. Attributes include a fast interconnect and more than 30 TeraBytes of Redundant Array of Integrated Disks (RAID) Fibre Channel Attached Storage.

The addition of this state-of-the-art HPC resource will further advance image processing research for Space Situational Awareness supporting the Air Force Maui Optical & Supercomputing Site mission.

Physics of Optical Properties of Aging Spacecraft Materials

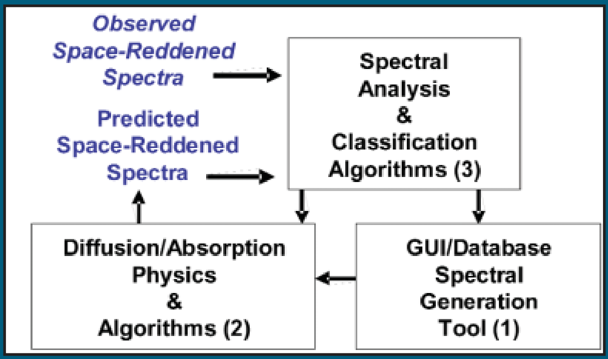
Current AMOS research directed at space weathering phenomena has successfully met its goals of producing a graphics-interface-based application which allows users to generate expected spectra of material/coating combinations. AMOS researchers have matched the spectra to observed spacecraft spectra, classifying spectra into reddened and non-reddened groups using advanced statistical techniques, and have established preliminary links between the physics of refraction and diffusion and the observed reddening and darkening phenomena.

During the next three years, the research scope will be expanded by closing the physics-observation-simulation loop by refining existing diffusion/absorption algorithms and incorporating additional spectral classification techniques, with the goal of utilizing differences between observations and predicted spectra to provide corrections to the database/spectral generation tool. In addition, the research will extend the region under consideration further into the infrared.

Specifically, the proposed research has the following objectives:

- Continue to refine the Spectral Generation Graphic User Interface (GUI) and diffusion/absorption physics algorithms and "close the loop" with the potential of aiding the identification and dating of spacecraft.

- Increase the spectral band under consideration from 0.4–2.0 um to include near-infrared 0.4–2.5 um, in order to provide additional spectral information.



This research is being conducted under the direction and funding of the National Aeronautics and Space Administration.

Haleakala Chosen as Site for the Advanced Technology Solar Telescope

The world's largest instrument for studying the Sun and its complex magnetic field, the Advanced Technology Solar Telescope (ATST), is one step closer to reality, and to a location on Haleakala, Maui. The ATST project is a potential new facility in the University of Hawaii, Institute for Astronomy's Haleakala Observatory Long Range Development Plan. It is an international project led by the U.S. National Solar Observatory (NSO), which is operated by the Association of Universities for Research in Astronomy (AURA), a consortium of 36 universities. The AURA Board of Directors endorsed the recommendation of its ATST Science Working Group to make Haleakala the primary candidate site for the ATST.

The $161 million ATST has been described as the world's greatest advance in ground-based solar telescope capabilities since Galileo. At 4 meters in diameter, the ATST will be the world's largest and most capable solar telescope. Its unique design is optimized to allow precise measurements of solar magnetic fields, particularly under circumstances where they have been, thus far, invisible. This new capability should allow us to understand and predict solar variability.

Understanding and predicting the magnetic fluctuations of the Sun is one of the few astrophysical research disciplines that is directly relevant to life on Earth. This variability touches Earth in several ways, principally through the sun's changing brightness, which affects the terrestrial climate both on the very long timescales that correspond to the rise and fall of civilizations, and the very short time scales of a few years. Furthermore, much Earth-bound technology, from electrical power distribution to cell phone communication, is directly affected by the intense solar magnetic storms that scientists call flares and coronal mass ejections.

Dr. Rolf-Peter Kudritzki, director of the Institute for Astronomy at the University of Hawaii, expressed his excitement about the site selection by saying, "The ATST is an outstanding scientific project. It will provide deep insight into the role that the Sun plays in our lives. I am extremely happy that we are now able to attract this project to Hawaii." He announced that "the ATST project is moving to undertake a joint State/Federal Environmental Impact Statement for a site on Haleakala."

For additional information visit http://www.ifa.hawaii.edu

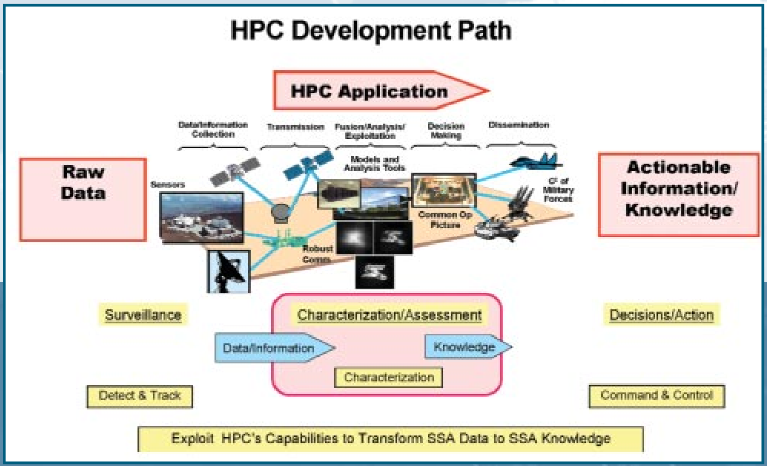
Department of Defense Awards Institute to AMOS

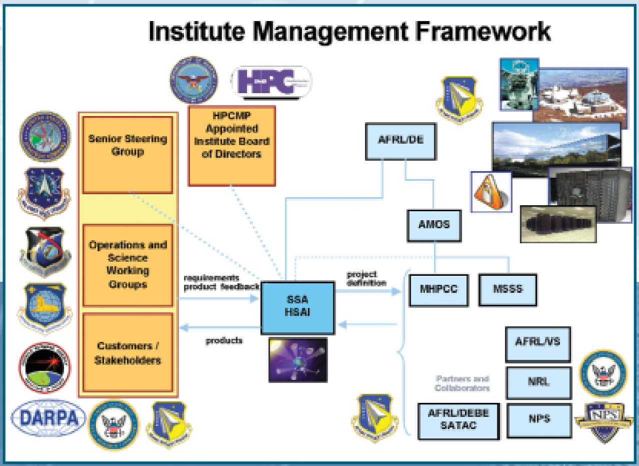
The Deputy Under Secretary of Defense (Science and Technology) selected the first High Performance Computing Software Applications Institutes (HSAI) on 20 August 2004. Each Institute receiving this prestigious award will form a critical mass of experts keenly focused on using computational science and High Performance Computing (HPC) to accelerate solving the Department's highest priority challenges. With cross-Service and Agency teaming and multi-disciplinary approaches, the Institutes were selected on the basis of strong potential to make important advances in Research, Development, Test, and Evaluation.

The Air Force Research Laboratory (AFRL) Directed Energy Directorate's Air Force Maui Optical & Supercomputing (AMOS) System was selected as the High Performance Computing Software Applications Institute for Space Situational Awareness (SSA). Home to the largest telescope in the DoD inventory, AMOS has a crucial role in acquiring, processing, and disseminating satellite data as a contributing sensor. AMOS is also home to one of the largest DoD supercomputing sites, providing world-class HPC capability and advanced software development services to the DoD, research, science, and warfighter communities.

The Institute will address two top priority capability shortfalls in the SSA community: space object characterization/change detection, and the development of a knowledge-fusion/knowledge repository. The Institute will apply the power of HPC and advanced algorithms to identify the functionality, capability, mission, status, and health of space objects. Also, by combining information from multiple sensors and multiple databases, knowledge fusion will enhance object characterization and data availability over current methods. These applications will enable the DoD to better perform their space control missions by providing them more accurate, more detailed, more complete, and timely information.

With the newly formed Institute, AMOS will extend its capability to provide cutting-edge HPC resources at the forefront of technology to the DoD, research, and warfighter communities.





AMOS spring 2005

Air Force Research Laboratory DETACHMENT 15

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2005 AMOS TECHNICAL CONFERENCE
SEPTEMBER 5-9, 2005 • MAUI, HAWAII

AMOS Air Force Research Laboratory DETACHMENT 15

AIR FORCE MAUI OPTICAL & SUPERCOMPUTING SITE

The Air Force Research Laboratory, Detachment 15 will hold the sixth annual AMOS Technical Conference on September 5-9, 2005 in Maui, Hawaii.

The conference has become internationally recognized as a signature event in the optical, computing, and space surveillance communities. Topical areas include laser applications, adaptive optics, high performance computing, astronomy, space weather, satellite metrics, orbital debris, and space object identification.

For additional information, visit www.maui.afmc.af.mil.